NOTES ON THE DWYKA COAL MEASURES AT VEREENIGING, TRANSVAAL, Etc.

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(Plate I.—Map.)

Situation, Etc.

The Vereeniging coal-mines are situate on the north side of the Vaal River where the railway crosses the river between Johannesburg and Bloemfontein. Height above sea-level at the station is 4,750 feet. The surface below which the coal occurs is fairly level. On the south side of the river is the Cornelia coal-mine, about 1½ miles distant from the Vereeniging shaft. These mines are opened up and worked on a large scale, having a daily output of about 1,000 tons of coal. I am indebted to the courtesy of the owners and the manager, Mr. Goodwin, for the opportunity of examining the geological evidence laid bare in the workings.

Geology.

Along the railway line from Elandsfontein to Vaal River, the Rand Beds of auriferous conglomerates, quartzite, shales, and intercalated diabase rocks are crossed for a few miles, then a belt of Lydenburg Beds (dolomite) until 2 miles south of Meyerton Station, where the Dwyka conglomerate crops out and the coal measures. Southward from this the Dwyka conglomerate and accompanying coal measures go underfoot, and they do not crop out again at the surface for hundreds of miles; they reappear on the south side of the basin running from Matjesfontein past Prince Albert to Grahamstown. The western, southern, and eastern extension of the Dwyka conglomerate was laid down in my report to the Cape Government in 1886, and the northern limit is now added in the accompanying plan.

The Dwyka conglomerate is directly overlaid by the black carbonaceous shales all round the enormous area enclosed by that rock; at Kimberley these shales attain a thickness of 240 feet, and some of the beds carry 9 per cent. of carbon. At Vereeniging the coal seams lie either immediately upon the conglomerate or there is black shale intervening for a few feet with black shale again above the coal. It follows that the Dwyka conglomerate is a splendid

bench mark; below its main body it is useless to search for coal, but above it, either directly or in some cases perhaps at a considerable height above it (because the conglomerate was in places unevenly deposited, and was probably levelled up before the coal seam was deposited), the coal measures and coal were laid down.

North of Kimberley the Dwyka conglomerate is exposed, and near the Vaal River again on the south bank at varying distances up to Parys in the Free State, then it turns northward, passing 2 miles south of Meyerton Station, and again crosses the Vaal to the south bank a little east of Vereeniging, continues along the Vaal River until south of Heidelberg, where it encloses the South Rand coal-field on the north side of the Vaal, as shown on Mr. Sawyer's geological plan of that area, turns south and crosses the Vaal River into the Free State, then turns northward and passes a few miles east of Heidelberg, Transvaal, and on to the Wilge River, then turns easterly and passes to the south of Middelberg, turns up towards Steenkamp's Berg, and thence runs south-easterly along the east slope of the Drakensberg, past the Slangapies Berg and southward through Zululand to the junction of the Mooi and Tugela Rivers in Natal. This gives a total length of the area occupied by the Dwyka conglomerate and its accompanying coal measures of 800 miles from Middleberg, Transvaal, to near Karroo Poort, Cape Colony, and an extreme width of 350 miles between Kimberley and East London. Outside of this area outliers occur at many places, the Zyferfontein and Boksberg coal-fields in the Transvaal belonging to this same horizon, and east of Boksberg undisturbed Dwyka conglomerate exists, while the denuded material from the conglomerate covers considerable areas of the older rocks on the north side of the Vaal River.

The length of the outcrop of the Dwyka conglomerate and accompanying black shales, coal, &c., exceeds 2,000 miles. In 1886 the black shales and other strong indications of coal, and in places thin seams of coal, also were known. Now with the light thrown on the subject by the Vereeniging and other extensive coal-mines along the northern edge of the area, the argument formerly advanced that the poverty of the outcrop in coal argued against coal in quantity existing in workable seams further into the basin falls completely to the ground, for such coal seams as are now being worked within the northern rim of the area are simply phenomenal, ranging for 6 feet of workable coal to over 60 feet.

In 1886 the probability of Sub-Karroo coal was predicted on geological grounds alone. The realisation far exceeds the most sanguine expectations, for at the horizon indicated excellent coal in

seams of abnormal thickness is being turned out in thousands of tons weekly in the Transvaal and Natal.

These great seams that are being worked so extensively in the Transvaal dip away underfoot in the Free State, and should be cut at about 1,500 feet at Bloemfontein. In the Cape Colony a bore where the railway crosses the Orange River from Kimberley should cut the coal measures within 300 to 400 feet or less. The dip of the coal measures from Kimberley is southwards, and near De Aar on the one side of the high ground and Cradock on the other are the likeliest points upon the Port Elizabeth to Kimberley line at which bore-holes should succeed.

Mr. A. R. Sawyer, of Johannesburg, has not only bored extensively over the South Rand coal-field, but he has also sunk a large shaft 582 feet deep here, and opened out upon a seam of coal 54 feet thick having a thin parting of sandstone 12 feet from the top. This coal is reported of excellent quality. Here sandstone, shale, and dolerite, to a thickness of over 100 feet, intervene between the coal and the Dwyka conglomerate below, but they appear quite conformable, and this negative fact has no weight against the positive evidence afforded at Vereeniging. Mr. Sawyer most fully endorses the view that his coal seam is of Sub-Karroo age, and his borings amply confirm this view. At Vereeniging the results of over twenty borings were placed at my disposal, and out of these eight showed the coal resting directly upon the Dwyka conglomerate, in the others black shale from 1 to 19 feet thick intervened.

At Vereeniging the Dwyka conglomerate consists of angular fragments, boulders, pebbles, &c., of quartzite, sandstone, shale, chert, dolomite, diabase, &c., and conglomerates both from the Rand Beds and the Lydenberg Beds, all such materials as might be derived locally, and ranging in size from grains of sand up to two and three hundredweight a piece. This material lies scattered without order or arrangement through a fine light grey clay, which is used extensively for making firebricks, &c., and locally termed fireclay. This Dwyka conglomerate shows by its general condition, by the forms of the included boulders, &c., and by the striated faces of the pebbles, boulders, &c., that it is of glacial origin. There appears to be a rude kind of bedding observable where this conglomerate is excavated for making firebricks as though it had been deposited in water. However deposited, there can be no doubt as to its being of glacial origin.

The very important point is that the upper portion of the conglomerate *shades by degrees into a carbonaceous shale* in places, further, *root-markings of carbonised matter* penetrate into the con-

glomerate at right angles to the almost horizontal surface, and these embrace, in some cases, boulders covered with striations.

The Dwyka conglomerate in fact forms the "underclay" or "seat-stone" of the coal seam in which plants actually grew, and this has hitherto been supposed not to occur in South Africa—it certainly does not occur in the Stormberg coal-field.

But the Dwyka conglomerate does not only form the floor on which, in some cases, first black shale then coal was deposited, but through the seam of coal itself, at many levels between the floor and the roof, pebbles and boulders also of glacial origin are met with, some weighing over a hundredweight each.

Then again, what is still more conclusive, the roof of the coal at Vereeniging is formed by a bed of conglomerate from 1 inch to 18 inches thick, and this, though generally of small pebbles of quartz and shale of greenish colour, contains strewn through it many larger boulders, pebbles, and angular fragments, some of them not only of the forms characteristic of glaciation, but also well striated.

Here is a case of coal being deposited under conditions the reverse of what is generally held to be favourable to the growth of such a luxuriant vegetation as would be required to furnish many feet of coal. For while the basal glacial conglomerate was as yet newly deposited, vegetation flourished upon it, then coal became deposited; while this was in progress glaciated pebbles were dropped into the seam, and then above all glaciated material was again deposited, some of the boulders being partly in the coal, partly in the conglomerate above it.

The section of the main shaft at Vereeniging is as under :—

Surface soil	2·0
Grey soft shales (pyrites)	30·0
Black micaceous shales and pyrites forming beds up to 6 inches thick (calamites abundant at base)	30·0
Conglomerate (glacial)	1·0
Good coal	9·0
Black carbonaceous shale	5·0
Floor Dwyka conglomerate, shading into carbonaceous shale at top.	
On the south side of the mine the section of the Cornelia shaft is alluvial sand and clay, pebble bed at base	51·3
Clay shale	3·9
Soft micaceous sandstone	106·7
Dark grey carbonaceous shales	7·6
Soft micaceous sandstone	1·0
Dark grey carbonaceous shale	42·8
Coarse grit	4·8
Dark grey carbonaceous shale	27·10
Dark micaceous shale	77·0

Coal	1·9
Grit and pyrites	·6
Dark carbonaceous shale	21·0
Coal	6·0
Micaceous shale	1·3
Sandstone and dark carbonaceous shale	44·9
Coal (inferior)	22·0
Sandstone and shale	8·0
Conglomerate	1·0
Coal (good)	13·0
Shale	5·0
	446·6

Floor Dwyka conglomerate.

At No. 10 bore-hole, near Cornelia shaft, the section is alluvial sand and clay, with pebble bed at base	52·0
Shale	8·0
Coal (inferior)	3·0
Shale	2·0
Coal (inferior)	18·0
Micaceous sandstone	14·0
Dark micaceous sandstone	30·0
Coal	11·0
Shale	2·6
Coal	8·6
Shale	4·6
Conglomerate (coaly partings)	8·0
Coal	13·0
Shale	·6
Sandstone and conglomerate	5·0
Coal	4·6
Shale	3·0
Carbonaceous shale	1·0
Conglomerate	·6
Coaly shale and pebbles	5·6
	194·6

Floor Dwyka conglomerate.

These three sections will serve to show how variable the constituents of these coal measures are within even a very limited area.

It is a remarkable feature of the Ecca Beds and the Dwyka conglomerate that wherever they are cut even hundreds of miles apart the sequence of the beds is much the same, and that beds having certain characteristics are easily recognised at vast distances apart. For instance, at Grahamstown, above the black and soft light-coloured shales there is a bed of what is called "Hone Stone" —shales that break up into angular, narrow strips about 1 inch thick. This very same peculiarity recurs at the junction of the Vaal and Orange Rivers, also at Pietermaritzburg and elsewhere. Again

the black shales are invariably overlaid by lighter coloured softer shales, a thin cherty band occurs some distance from where the black shale is met with at Grootfontein, and this is again met with at the junction of the Orange and Vaal Rivers. These facts indicate that over an immense area and under exactly similar conditions these beds were deposited, possibly in a very extensive shallow lake.

In my 1886 edition of the *Geological Map* I included within the Stormberg coal measures all the coal outcrops then known, but recent facts necessitate an alteration of the boundary, and it will be interesting to make out the proper extension northward of the Stormberg coal measures.

The Coal Seam.

At Vereeniging the coal seam is as follows: At the base is the Dwyka conglomerate known locally as "fireclay"; it is about 50 feet thick and rests upon Lydenburg Beds. This conglomerate is thickly studded with boulders, pebbles, &c., that are striated and glaciated. The upper portion shades gradually into a carbonaceous sandy shale in some places, and is thickly penetrated with root-marks runnin vertically into it, the general surface being fairly horizontal. This is a true "underclay" or "seatstone," and it is locally termed "fireclay" because the upper portion when separated from the stones is made into firebrick, &c. This conglomerate is rudely bedded.

Above the conglomerate in places there is a bed of black shale with plant remains. The top of the shale is uneven, and then comes the coal seam, which ranges from 6 feet to 15 feet thick and averages 9 feet. The coal is much laminated and hard; thin bands of iron pyrites occur near the top of the seam. A thin parting of sandstone 1 inch thick occurs about 3 feet below the roof. (A similar parting is found in Mr. Sawyer's 54 feet coal seam).

Pebbles and boulders are found embedded in the coal at al horizons; these are in some cases clearly glaciated.

Above the coal is a band of conglomerate from 1 inch to 18 inches thick, with small pebbles principally, but at frequent intervals pebbles of large size and some boulders occur, some of them partly embedded in the coal and partly in the conglomerate forming the roof of this coal seam. Many of the pebbles are striated and glaciated.

Just above the conglomerate are black micaceous shales thickly studded with the interlaced stems of calamites, the former plant now represented by a flattened thin seam of coal. There must have been a dense forest of these plants to supply the prodigious number of prostrate stems. In width these casts range up to over 12 inches, and in length up to 60 feet. The stems are fluted lengthways, and

at every 2 or 3 feet are joints and bud-marks. Above are more shales, &c., very carbonaceous as a rule.

In the coal seam Mr. Leslie found a stem about 7 inches through standing vertically in the coal and probably where it grew.

The coal from this seam is said to run about 15 per cent. ash.

Near the Cornelia shaft in No. 10 bore on the south side of the rivers the section gives a thickness of 58 feet of coal, though some of the seams are of inferior quality.

The Stormberg coal seams present quite a contrast to the seams worked at the northern end of the Dwyka coal measures. The former are lean, the compound seams seldom exceeding 6 feet of coal, and the ash exceeds 20 per cent. In the Vereeniging, Middleburg, and South Rand coal-fields the coal seams range from 6 feet up to 60 feet, representing a mass of vegetation hundreds of feet in thickness; and this implies an exuberant growth of plants of a phenomenal character, and the percentage of ash of these coals never reaches 20 per cent.

The Stormberg coal seams occur at an horizon *above* the Karoo Beds and the Ecca Beds, the whole thickness of which intervene between the Stormberg coal seams and the underlying Dwyka coal seams. This represents a vast epoch in time, and in consequence the flora is very distinct in the coal measures of the one horizon from those in the other.

Fossils.

Mr. Leslie, of Vereeniging, who very kindly allowed me to examine his collection of fossils, and who showed me over the various localities, takes a keen interest in the fossils from a buff-coloured sandstone that occurs higher up in the series than the carbonaceous shales; here he obtained Nœgerathiopsis Hislopi (found also at Kimberley), Myiston cyclopteroides, two or three species of Glossopteris, Phyllotheca, Sigillaria Brardi, Calamites, &c. Mr. Sawyer at the Rand coal-field has obtained Sigillaria Brardi right in the coal itself. The above fossils are all to be seen in the Geological Society's collection at Johannesburg, Mr. Draper having secured some excellent examples.

None of the above fossils have been noticed in the Stormberg coal measures where the prevalent forms are Pecopteris, Thinnfeldia odontopteroides, Podozamites elongatus, Tæniopteris Daintreei, Baiera Schencki, Equisetaceæ, &c., and the very characteristic ferns with bifurcated stems. These fossils so characteristic at the Stormberg are not met with at Vereeniging.

Messrs. Seward and Zeiller, from an examination of the fossil

flora obtained at Vereeniging, &c., by Mr. Draper, and as a result of their thoroughly accurate determinations, decided that such fossil plants were from a much older horizon than the Stormberg, and though they had never seen the locality were able to correct the mistakes of local observers.

At Wesselton diamond-mine near Kimberley a piece of sandstone from these Ecca Beds was found with well-preserved fossil fish on it. Mr. Gardner Williams has the specimen. At Kimberley mine small sauroid remains have been found from time to time in the grey shales above the black shales.

Conclusion.

When my 1886 report was written there was no workable coal known to occur within the margin of the area outlined by the Dwyka conglomerate (Pl. I), and the northern limit of the conglomerate remained to be filled in. Now this northern course of the conglomerate is known, and it is found that within these bounds, and above the Dwyka conglomerate sometimes resting directly upon it, there are coal seams of enormous thickness and apparently extending over immense areas. Formerly the question was, Do coal seams of workable character occur at the horizon of the Ecca Beds? This question is now most fully answered in the affirmative by such extensive deposits as are worked at Vereeniging, Middelberg and the South Rand coal-fields.

The question remaining now is, How far south do these abnormally thick seams of coal extend? This is partly answered by the occurrence of great bodies of broken coal, fireclay, iron pyrites in large nodules, and black shales with impression of glossopteris and calamities all mixed together in faults at the Camdeboo and near Beaufort West. It is scarcely to be expected that over an area 800 miles long, and from 150 to 350 miles wide, an unbroken seam of coal exists, but that there are great areas within the margin of the Dwyka conglomerate of workable coal is now proved at the northern end, and systematic drilling would doubtless soon result in proving extensive coal seams to exist in other portions of the basin.

At East London probably the coal may be found nearest to the seaboard; Port Elizabeth might draw supplies from near Cradock, and Cape Town from near Beaufort West; but unless active operations in the way of boring are undertaken it is very certain that the Sub-Karroo coal will not supply fuel at a cheaper rate to the railways nor assist the development of Cape Colony by furnishing fuel for passing merchantmen and ships of war, provide fuel for pumping water on to the Karroo soil, nor supply household grates with fuel at reasonable rates.